

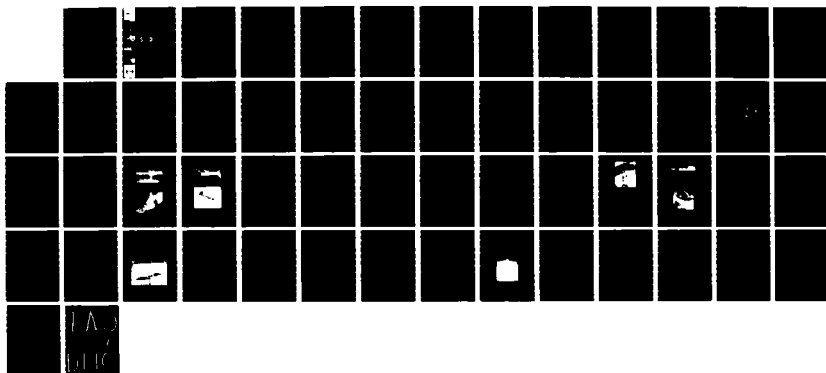
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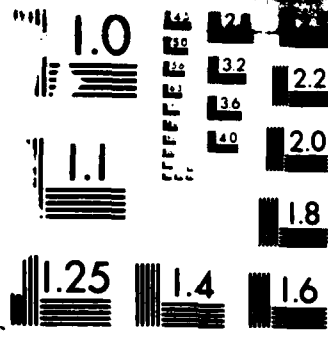
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LONG-TERM EFFECTS OF
DREDGING OPERATIONS

MISCELLANEOUS PAPER D-86-6

SURVEY OF EQUIPMENT AND CONSTRUCTION
TECHNIQUES FOR CAPPING DREDGED MATERIAL

by

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20. ABSTRACT (Continued).

Experimentation with the capping procedure has revealed significant facts concerning the behavior of such disposed material in the Long Island Sound and at the New York Mud Dump Site. The monitoring equipment and techniques developed by Science Applications, Inc., in the course of their work with the Disposal Area Monitoring System (DAMOS) Program for NED, have created much background knowledge that can be built upon as the capping concept is perfected and applied to other regions of the country.

At present, the limiting physical conditions that would permit a satisfactory capping operation are known only in approximate terms. No specific criteria have been developed for the capping procedure. There are many places in the United States that do not possess the natural physical conditions suitable for the capping concept employed in NED and NYD. Borrow pits and excavations may provide artificial locations for infrequent and emergency use.

The equipment employed in work done to date was conventional and was operated in conventional fashion. There is equipment available now that if properly employed would improve the quality of each phase of the disposal/capping process. Such currently available equipment includes precision electronic positioning systems for navigation and surveillance, split hull hopper dredges, and self-propelled hopper barges for transporting and disposal. Some innovations that should be required where applicable are closed grab buckets for wire line dredges and ladder pumps for increased slurry density in hydraulic dredging. Such equipment, if specified, will immediately improve the procedure.

Equipment that could be constructed with existing technology includes ladder bucket dredges that produce high density material with less turbidity than other mechanical dredges and operate with more precision and increased production. This "old" dredge type is recommended to be adopted as a research and development project by the Corps of Engineers and could lead to much improved harbor dredging. The capping concept requires precision placement of the dredged and capping material. Lessons learned by the Japanese may be worthwhile innovations. Their need for precise control led to the use of self-unloading barges that conveyed the materials to the bottom by the use of tremie pipe. Carefully controlled spreading techniques were used. Hydraulic and mechanical systems are explored in this regard.

The concept of capping contaminated material deposited in open water has the potential for mitigating some serious disposal conditions. It will not work universally, and much needs to be learned about the behavior of underwater disposal sites before the potential can be fully exploited. Work to date highlights the importance of making accurate predictions concerning soil engineering, coastal and ocean engineering, as well as equipment performance characteristics. Trials should continue with careful monitoring and coordinated record keeping in order to generate credible data upon which to base performance predictions in diverse physical conditions and geographical locations.

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PREFACE

This report was prepared by The Sand Hen Corporation, Wilmington, North Carolina, for the US Army Engineer Waterways Experiment Station (WES) under Contract No. DACW39-83-M-2626, dated 16 May 1983. The WES funding was through the Long-Term Effects of Dredging Operations (LEDO) Program work unit, Efficiency of Capping in Reducing Cumulative Effects of Dredged Material Discharge. The LEDO Program is assigned to WES under the management of the Environmental Effects of Dredging Programs (EEDP), Environmental Laboratory (EL).

The report was prepared by Mr. William H. Sanderson and Mr. Arthur L. McKnight of The Sand Hen Corporation. The contract was managed by Dr. Raymond L. Montgomery, Chief, Environmental Engineering Division (EED), WES. The work was conducted under the general supervision of the late Mr. Andrew J. Green, former Chief, EED, and Dr. John Harrison, Chief, EL. Mr. Charles C. Calhoun, Jr., and Dr. Robert M. Engler were the managers of the EEDP during preparation of this report. Technical Monitors were Dr. Robert Pierce and Dr. William Klesch, OCE, and Mr. Charles Hummer of the Water Resources Support Center, Fort Belvoir, Va. The report was edited by Ms. Jamie W. Leach of the WES Information Products Division.

Important assistance was provided to the authors by Mr. Vyto Andreliunas, Chief, Operations Division, New England Division, and Mr. John Zammit, Chief, Operations Division, New York District. Significant contributions were also made by Dr. Robert W. Morton, Director, Ocean Science and Technology Division, Science Applications, Inc.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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CONTENTS

	<u>Page</u>
PREFACE.....	1
LIST OF FIGURES.....	3
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT.....	4
PART I: INTRODUCTION.....	5
Background.....	5
Purpose and Objective.....	6
The Capping Concept.....	7
PART II: EVALUATION OF EXISTING CAPPING TECHNIQUES.....	8
General.....	8
Survey Methods.....	11
Description of Materials.....	18
Monitoring Procedures.....	18
Physical Site Conditions.....	19
Evaluation of the Capping Demonstration.....	20
PART III: POTENTIAL IMPROVEMENTS.....	22
Conventional Dredging Equipment.....	22
Dredge Plant Currently Available.....	30
Special Plant Requirements.....	32
PART IV: CONCLUSIONS AND RECOMMENDATIONS.....	41
Justification for Capping.....	41
Dredging Improvements.....	42
Hauling Equipment.....	43
Positioning and Surveillance Technique.....	44
Monitoring by Hydrographic Survey Methods.....	44
Disposal Technique.....	47
Planning Imperatives.....	48
REFERENCES.....	51
BIBLIOGRAPHY.....	52

LIST OF FIGURES

No.		Page
1	Summary of locations of the dredged material dump site from pre-1888 to the present.....	9
2	Locations of dredged material dump sites in the region of Long Island Sound, and in the New York Bight.....	10
3	Location of Central Long Island Sound Disposal Site.....	10
4	Bathymetric survey grid 600 m long with 25-m spacing and the computer-plotted track of the survey vessel.....	12
5	Bathymetric survey of the contaminated material mound at the Stamford-New Haven north site prior to capping.....	13
6	Bathymetric surveys at the Stamford-New Haven north and south disposal sites shortly after placement of the cap material.....	14
7	Bathymetric sections showing the small-scale topography along the four lanes of the survey grid passing across the Stamford-New Haven south site dredged material mound.....	15
8	Three depth transects along one of the survey grid lines through the Stamford-New Haven south site dredged material mound before, during, and after disposal operations.....	15
9	Mechanical versus hydraulic dredges by project.....	22
10	Grab bucket dredge.....	26
11	Watertight clamshell bucket during field studies.....	26
12	Hydraulic dredges.....	27
13	Self-propelled barge under way.....	34
14	Corps of Engineers split hull dredge CURRITUCK.....	35
15	Hydraulic barge unloader and sand spreader.....	37
16	Conveyor unloading barge.....	38
17	Drag scraper adaptation to barge unloading.....	40
18	Tide gage installed in 1977, 3/5 mile seaward of Beaufort Inlet Bar, North Carolina.....	46



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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI
(metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
miles (US nautical)	1.852	kilometres
miles (US statute)	1.609347	kilometres
tons (2,000 pounds, mass)	907.1847	kilograms

SURVEY OF EQUIPMENT AND CONSTRUCTION TECHNIQUES
FOR CAPPING DREDGED MATERIAL

PART I: INTRODUCTION

Background

1. Open-water disposal of dredged material and other matter has been practiced since the earliest days of the development of this country. People have been concerned about the environmental effects of such disposal methods for many years. The passage of the River and Harbor Act of 1899, which instituted a measure of control of disposal in navigable waters, was one result for that early concern. The first, and still the most active, open-water disposal site in the country is the New York Bight and adjacent ocean waters.

2. Many of the Nation's most industrialized harbors must be maintained by dredging, and the sediments in these harbors now contain a wide variety of contaminants. The full effect of chemical pollutants on the marine environment is not known, but alternatives to open-water disposal of substances thought to be dangerous are constantly being sought. When alternative methods are not practical, mitigation measures have been mandated by a variety of Federal and state laws. Notable among these are the National Environmental Policy Act of 1968 et seq. Capping of dredged material with clean material from uncontaminated sites is a mitigation measure which has been seriously investigated by the US Army Corps of Engineers.

3. Monitoring of disposal sites in an effort to document data on the observed physical, chemical, and biological effects of dredged material began in earnest with the Dredged Material Research Program (DMRP) of the Corps of Engineers. Many facets of the effects of then-current practices were observed, measured, and studied. A scientific approach with systematic investigations of a multitude of situations and conditions was very productive. New discoveries have resulted in significant revision of some of the theories popular in the 1960s and 1970s and added to the knowledge of the environmental effects of dredging activities.

4. Certain short- and long-term effects of dredging were the subject of individual investigations of many task groups of studies sponsored by the US Army Engineer Waterways Experiment Station (WES). The developing science sug-

gested that some simple mitigation measures may be practical and acceptable solutions to the previously identified pollution problems. The Disposal Area Monitoring System (DAMOS) Program revealed many important findings in this regard.

5. Since 1979 the DAMOS effort has been concentrated on the study of active aquatic dredged material disposal sites in the waters adjacent to the New England area. The original DAMOS broad-based effort related to long-term monitoring, instrumentation development, and fisheries studies. The DAMOS Program is now providing a viable approach to monitoring and managing the disposal of dredged material in the Long Island Sound area. From these continuing studies, certain predicted responses to activities in other regions can be extrapolated.

6. Monitoring of the Mud Dump Site in the New York Bight Apex is continuing. Valuable data are being gathered on the constantly nourished mounds of disposed materials. A wide variety of materials are disposed constantly in the form of harbor sediments, sewage sludge, and debris. Clean sediments are also deposited from channel maintenance projects. The work at the active Long Island Sound dredged material disposal sites and the New York Bight Mud Dump are the activities examined in this report.

Purpose and Objective

7. This report is a principal part of a review and evaluation of certain WES study activities concerning the capping of dredged material deposited in open water. This study is concerned with previous and ongoing work associated with the monitoring of dredged material disposal activities in Long Island Sound and on the Mud Dump Site in the New York Bight Apex. The tasks of this effort included:

- a. Review of the work done by the New England Division (NED) and the New York District (NYD).
- b. Analysis of the dredging, hauling, disposal, and capping activities that have been documented.
- c. Evaluation of the monitoring that has been conducted by Science Applications, Inc. (SAI), the Corps, and others.

8. The objective of the study is to supplement the findings and conclusions of previous and ongoing scientific work with practical and useful engineering suggestions that may improve opportunities for wider application of

the capping concept. Such suggestions will focus on equipment, equipment innovations, and operating techniques.

The Capping Concept

9. Systematic and precise monitoring of the disposal sites mentioned above soon suggested that with careful planning and accurate execution of open-water disposal of certain toxic substances, the risk of environmental damage could be effectively mitigated. Considerable data have now been accumulated from repeated observations and precise measurements of dredging, disposal, and capping of deposits. The biological, chemical, and physical aspects of dredged material have been discussed in WES technical reports, as well as a number of DAMOS reports and individual technical reports and papers. Some of these will be referenced in this report. The concept of careful deposition and covering (capping) with a blanket of suitable sediment material is a practical and appropriate measure in situations where favorable conditions exist. In-depth study of field experiments has been restricted to the New England/New York sites, but some other locations afford similar opportunities. Unfortunately, however, many regions of the coastal margin of the United States are not physically suitable for the practice of capping as it is being done in prototype experiments.

10. In considering the capping concept, and in developing guidance for executing this disposal scheme, the entire process must be examined. The process includes the dredging operation, the transportation of the dredged sediments and capping materials, and the deposition of the contaminated sediments and the capping material. An activity that must be coincident with the process is an accurate measuring and monitoring program that will guide the operations and record the events so as to generate a complete record.

PART II: EVALUATION OF EXISTING CAPPING TECHNIQUES

General

Purpose

11. This section describes the experimental capping operations which have been performed to date by NED and NYD. The object of all of these efforts has been to isolate contaminated dredged material from the benthic fauna and from the water column; evaluate sand and silt as capping materials in terms of coverage, stability, and effectiveness in isolating contaminants; and evaluate biological recolonization potentials. The following paragraphs of this section will be divided between NED and NYD work (see Figures 1-3).

New England area

12. The NED contains several relatively small harbors located in heavily industrialized areas which must be maintained for the benefit of the local and national economy. Contaminants are present in several of these areas. Upland disposal areas are unavailable. The concept of capping disposal mounds with uncontaminated material was developed over 10 years ago and several experimental capping jobs have been performed.

13. Since 1979 and continuing into 1983, NED has dredged from several harbors approximately 190,000 cu yd* of contaminated material which required capping. All of this material was disposed in designated areas within the Long Island Sound Disposal Site. Capping material placed to cover the dredged material was approximately 353,000 cu yd. Material quantities used in this discussion are approximate. The data kept by the Corps are based upon the estimated volume within the barge or scow that transported the material from the harbor dredging area.

New York area

14. In the vast and complex areas of New York Harbor there are hundreds of docks, piers, slips, and harbor areas which must be maintained by private interests so that the commerce of the Nation's largest harbor can continue. Many such areas contain contaminated material and upland disposal areas are not available in this densely populated and developed area. Disposal at sea,

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

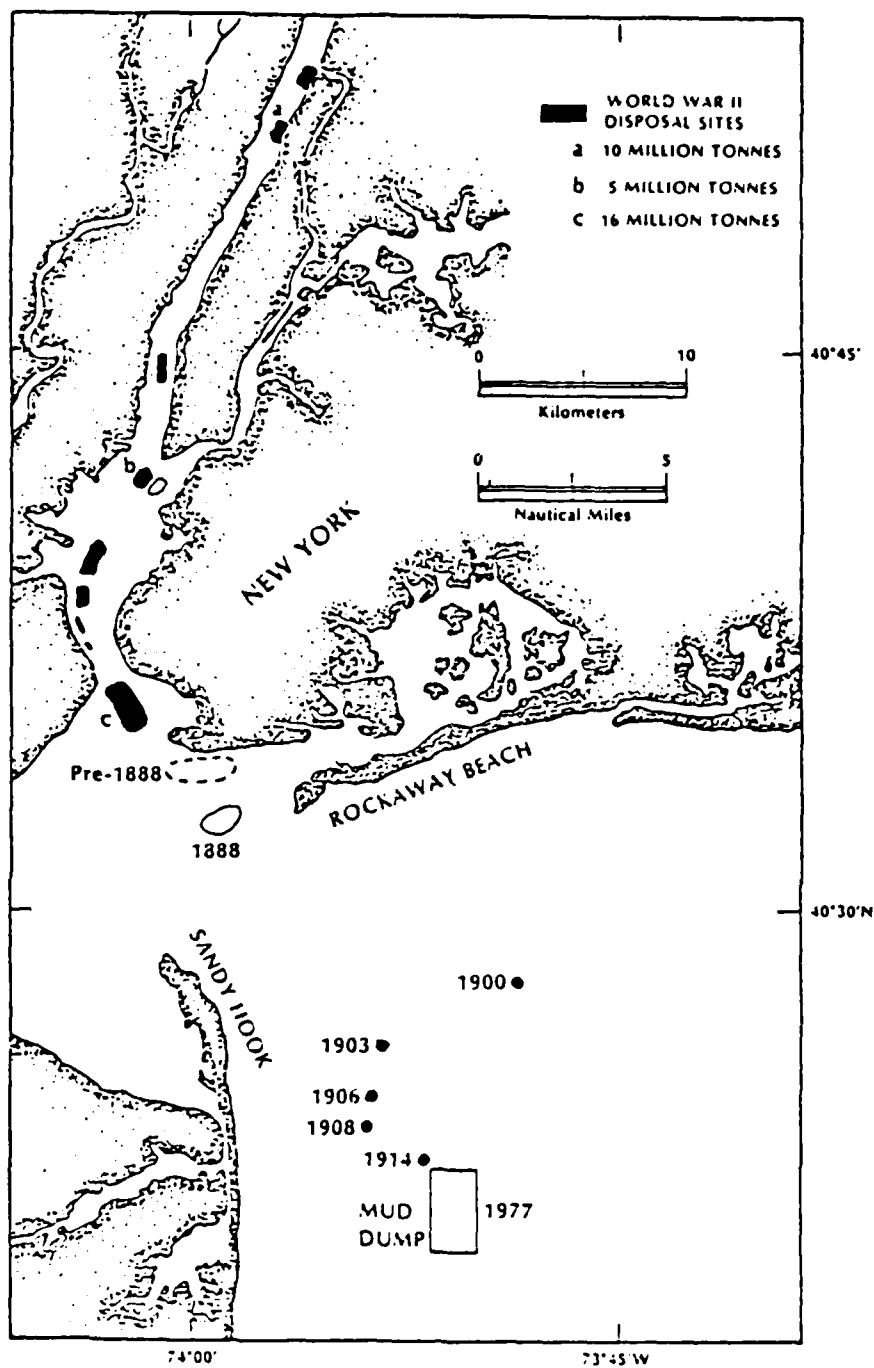


Figure 1. Summary of locations of the dredged material dump site from pre-1888 to the present (from O'Connor and O'Connor 1983)

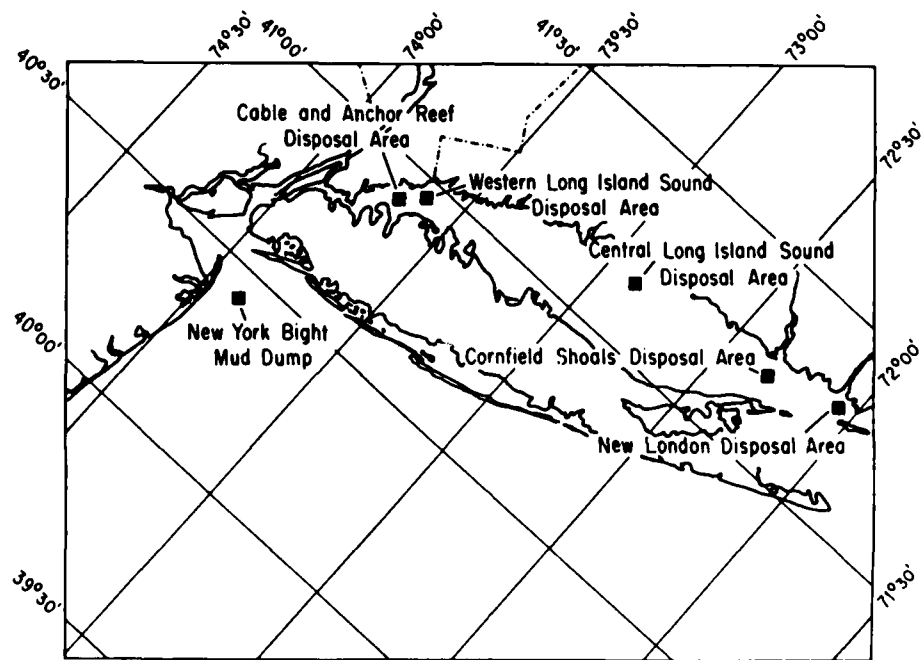


Figure 2. Locations of dredged material dump sites in the region of Long Island Sound, and in the New York Bight (from O'Connor and O'Connor 1983)

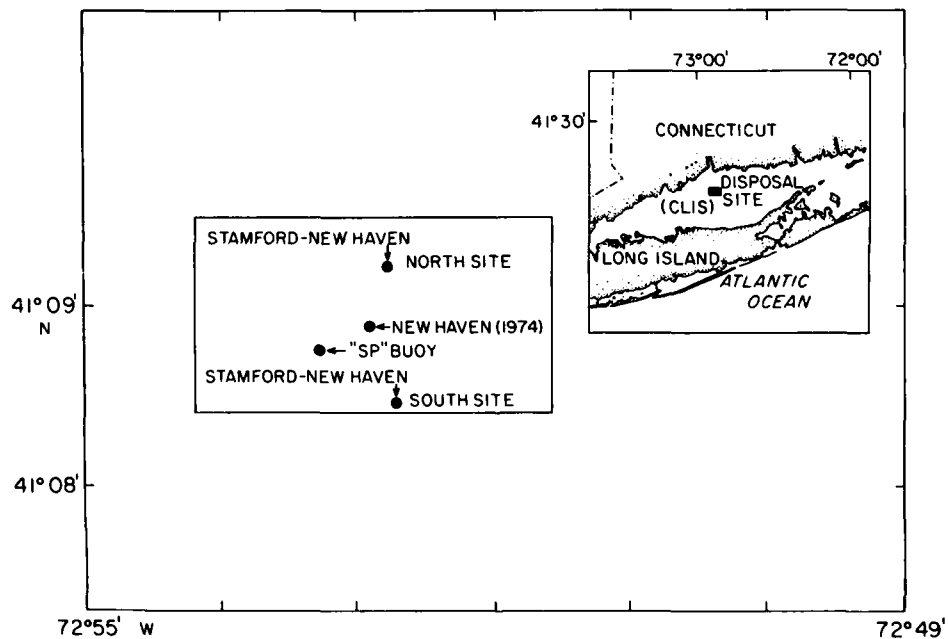


Figure 3. Location of Central Long Island Disposal Site (Morton 1983). The locations of three dredged material mounds within the site are shown. Figure used courtesy of Science Applications, Inc.

under permit from NYD, is the only alternative available, and for the past several years such operations have been permitted with the material promptly capped by clean material from Federal navigation projects maintained by NYD (Suszkowski 1981).

15. Since 1980, permittees under the NYD have dredged approximately 889,000 cu yd from slips, berthing areas, etc., and have disposed the material at designated disposal points in the open ocean Mud Dump Site (Suszkowski and Mansky 1983). Concurrent with this disposal, the Corps of Engineers has estimated that 2,506,000 cu yd of capping material has been deposited as cover for this contaminated material.

16. In both NED and NYD the capping operations have been coordinated with appropriate environmental agencies. These agencies have accepted the procedure after playing active roles in the postplacement monitoring of the areas.

Survey Methods

New England area

17. The monitoring of small changes in underwater topography resulting from accumulation or loss of dredged material requires that bathymetric measurements be made with extreme precision. It is imperative that the ability to perform replicate, precision surveys be developed. A computerized navigational and data collection method was developed by Morton (1983). This system consisted of a Hewlett-Packard 982A plotter interfaced with a Del Norte Tri-sponder system, an EDO 4034A fathometer, and an EDO 261C Digitrak Unit. Control stations ashore were located with an accuracy of ± 1 m. Since a computer was used, all corrections for vessel draft, sound velocity, and tides were made after completion of the survey. The fathometer was bar checked before each survey and adjustments were set at zero.

18. The first step was to establish a control grid to be used for pre-dredging, postdredging, and postcapping surveys (Figure 4). The heavy lines in Figure 4 are grid lines; the light lines are the computer-plotted track of the survey vessel. The grid area was 600 x 600 m with 25 transects spaced 25 m apart. Range data from the computer provided steering information to assist the helmsman in maintaining correct position and heading. Surveys were made only on calm days and errors of less than 5 m on either side of a given

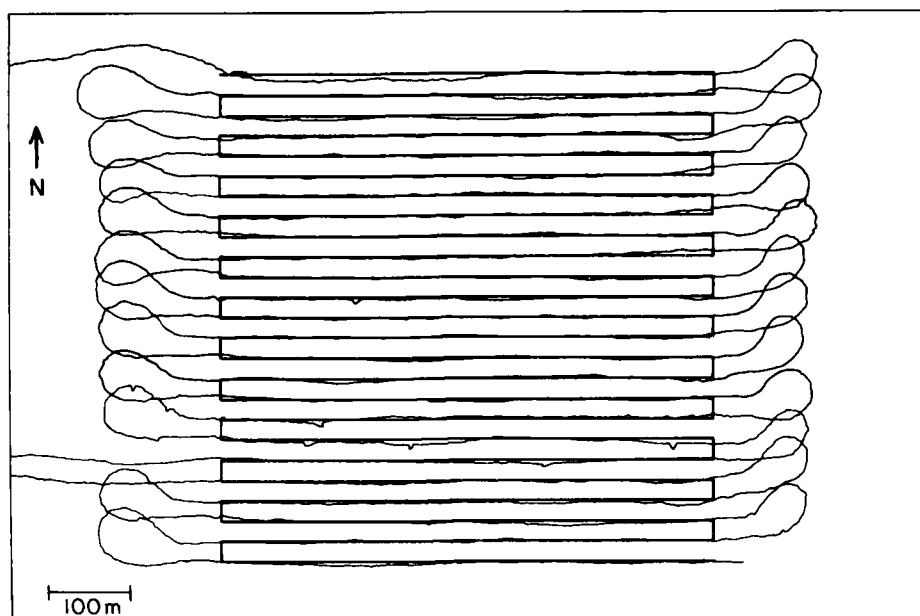


Figure 4. Bathymetric survey grid 600 m long with 25-m spacing (heavy lines with rectangular limits) and the computer-plotted track of the survey vessel (Morton 1983). Figure used courtesy of Science Applications, Inc.

transect were achieved. Data acquisition was controlled by the sampling rate of the Del Norte Trisponder unit, which is normally one range measurement per second. Depths were averaged over this 1-sec interval and recorded on cassette tape with corresponding time and position information.

19. Mathematical procedures were developed in order to analyze the bathymetric data collected. These procedures permitted plotting of the contour charts of the disposal area, and the topography of any lane line. Figure 5 shows the contours of the area after dredged material disposal had been performed but prior to capping operations. Figure 6 shows the contours of the area after placement of the capping material. Figure 7 shows topography along four selected grid lines with the heavy line showing predisposal conditions and the light line showing conditions after placement of the dredged material only. Figure 8 shows a typical grid line through the center of the area with the light line indicating the predisposal conditions, the heavy line showing conditions after placement of the dredged material, and the very heavy line showing the final condition after placement of the capping material.

20. The dredged material placed on the south site during the operation being described totalled 37,800 m³ (scow measurement). The survey indicated

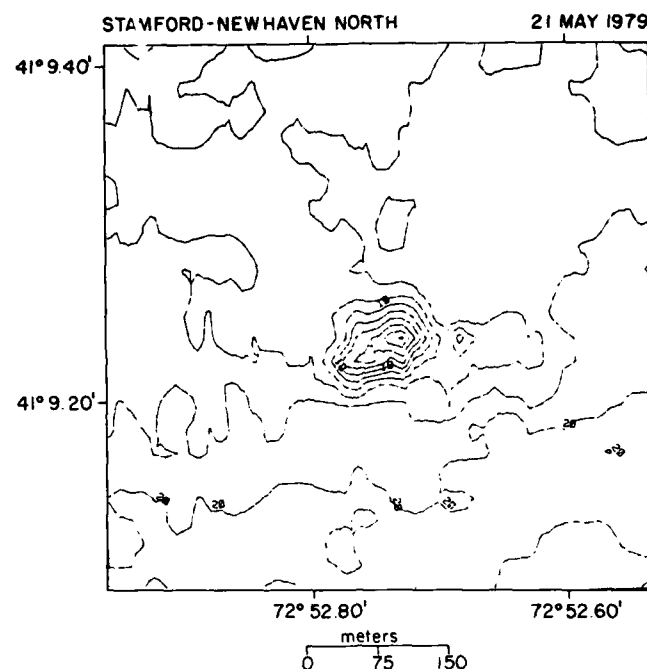


Figure 5. Bathymetric survey of the contaminated material mound (in metres) at the Stamford-New Haven north site prior to capping (Morton 1983). Figure used courtesy of Science Applications, Inc.

that the disposal method used was very successful in developing a small discrete mound about 100 m in diameter and 1.2 m thick. It was also indicated that $34,300 \text{ m}^3$, or about 90 percent of the dredged material, could be clearly discerned. One of the striking results of the survey was the rapid decrease in dredged material thickness at the margins of the mound. In the east and west directions the change from thickness greater than 50 cm to less than 5 cm occurred between 100 and 150 m from the disposal point. In the north-south direction the change occurred between 50 and 100 m. It was apparent that the cohesive nature of the dredged material was creating a definite mound with discernable boundaries. The capping material was dredged from New Haven Harbor totalling $76,000 \text{ m}^3$ (scow measurement), of which $72,000 \text{ m}^3$, or about 95 percent, was accounted for in the volume calculations. The above results were first reported by Morton (1980).

21. The survey methods described above were supplemented by diver observations and by underwater photography. The purpose of these operations was to verify bathymetric surveys, collect sediment samples, and investigate biological activity and/or physical changes.

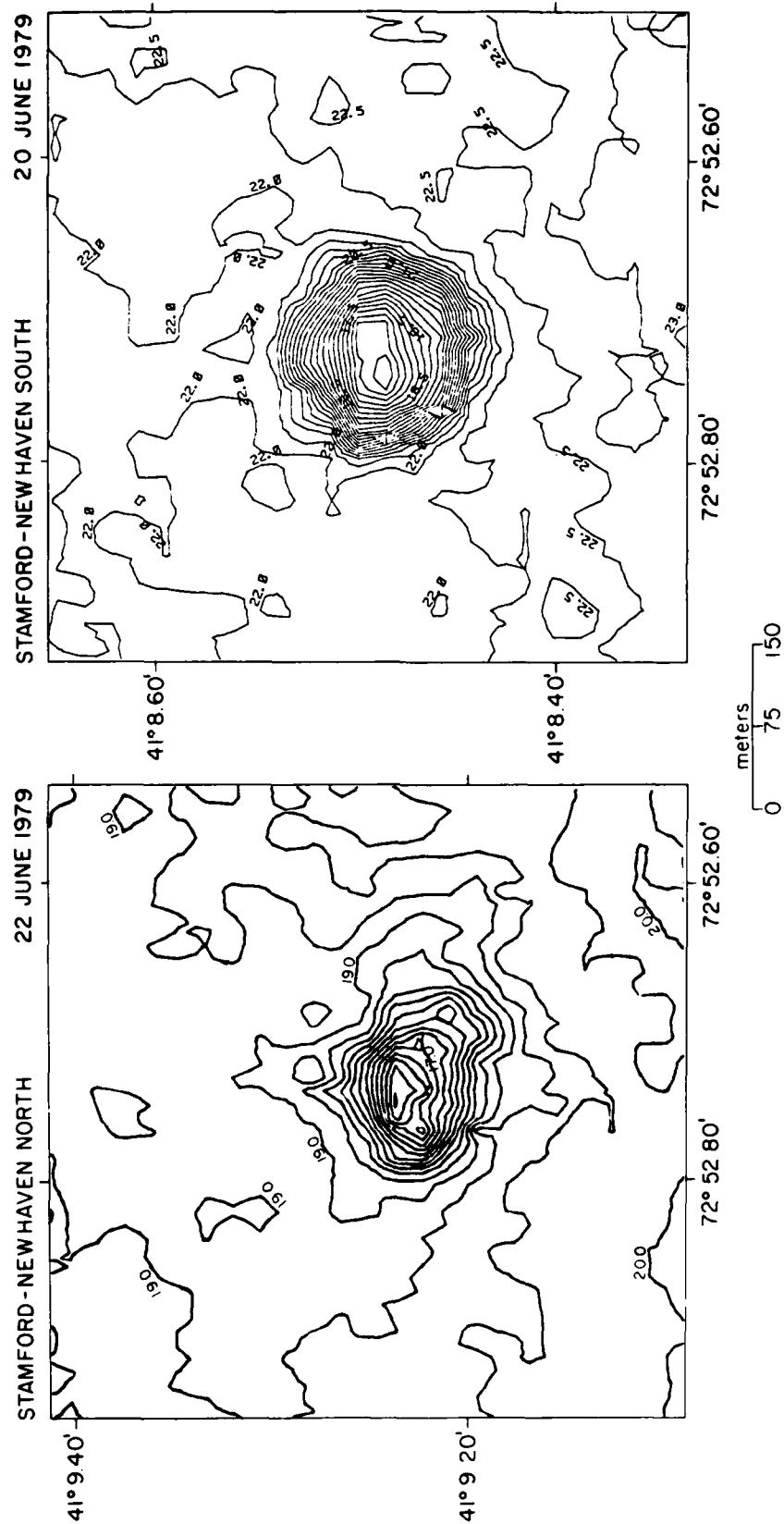


Figure 6. Bathymetric surveys at the Stamford-New Haven north and south disposal sites shortly after placement of the cap material (contour intervals equal 0.25 m) (Morton 1983). Figure used courtesy of Science Applications, Inc.

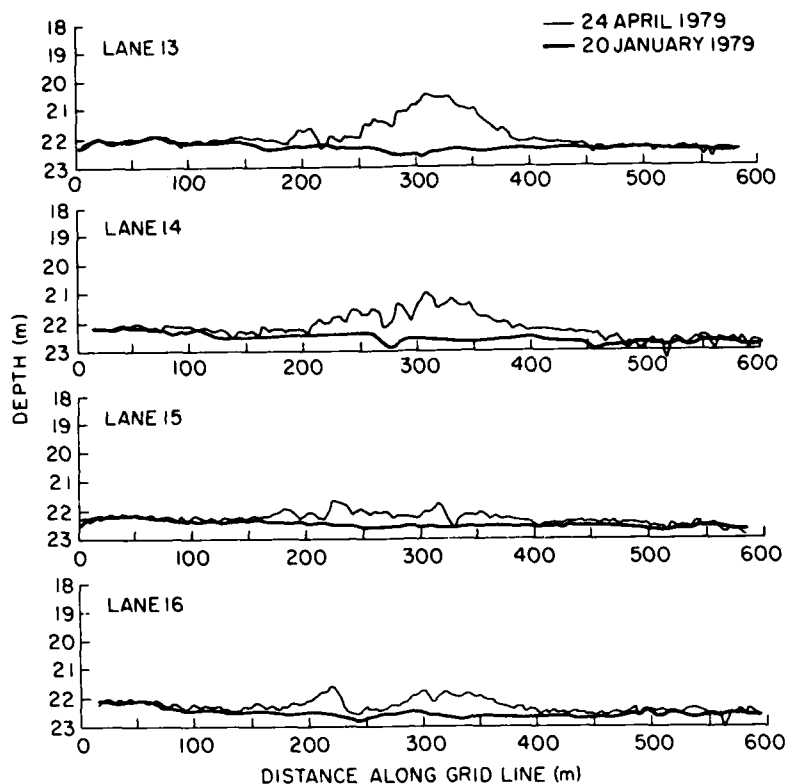


Figure 7. Bathymetric sections showing the small-scale topography along four lanes of the survey grid passing across the Stamford-New Haven south site dredged material mound. The interval between the lanes is 25 m and the vertical exaggeration is 25 times the horizontal scale (Morton 1983). Figure used courtesy of Science Applications, Inc.

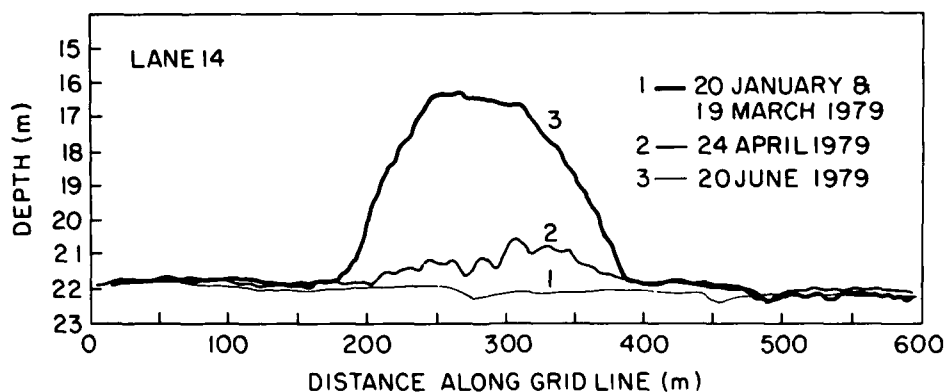


Figure 8. Three depth transects along one of the survey grid lines through the Stamford-New Haven south site dredged material mound before, during, and after disposal operations. Vertical exaggeration is 25 times the horizontal scale. The contaminated sediment was deposited between surveys 1 and 2 and the silt cap was added between surveys 2 and 3 (Morton 1983). Figure used courtesy of Science Applications, Inc.

New York area

22. Detailed information was not available for the work performed by NYD. However, it was apparent that survey procedures similar to those used by NED were employed with equivalent emphasis on the precision necessary in pre-dredging, during-dredging, and postdredging bathymetric surveys.

23. The NYD dredging was done by permittees rather than Federal navigation projects. All material dredged by permittees has been disposed by scow in the offshore Atlantic Ocean disposal area known as the Mud Dump Site. Two specific points within this rectangular area approximately 1.9 by 3.7 km in size were marked by taut-wire buoys. During the period between 8 March 1980 and 11 March 1982, about 889,000 cu yd of material was dredged by several permittees and disposed in the buoyed spots in the Mud Dump Site. Placement was by bottom-dump scows. Following the actual dredging, capping material totalling about 2,500,000 cu yd was placed over the dredged material. Of this amount about 1,044,000 cu yd, or about 42 percent, was placed by dump scows and the remaining 1,461,700 cu yd, or about 58 percent, by the Corps of Engineers' hopper dredge GOETHALS. All of this capping material was from maintenance dredging of Federal navigation projects. In the principal job (from 8 March 1980 to 15 November 1980), surveys revealed the capping material thickness to range from 6 ft at the center to 2 ft at the edge of the area. There were small jobs in which permittees were allowed to use a separate point within the Mud Dump Site on a repetitive basis with capping following each dredged material placement operation. Layers of dredged material and capping material repeated themselves and created what is described by NYD as de facto capping. These small jobs were not subjected to as close control as was the major 1980 work.

Disposal site control

24. The preceding paragraphs discussed the necessity of and methods for achieving extreme precision in the surveys conducted in the work to date. It follows that it is equally important to ensure that both the dredged material and the capping material are disposed accurately at a precisely designated spot. It is clear that no matter how accurate the surveys, if the dredged material and/or the capping material is disposed at random, even within the confines of a comparatively small area, the benefits to be achieved will be materially decreased.

25. In all of the NED operations, the exact desired disposal point has

been marked by an accurately located taut-wire buoy having variation from exact position of not more than 10 m. It is essential that the dump scow (or dredge if a hopper dredge is used) be adequately instrumented to achieve accurate placement of dredged material. Dead-reckoning to arrive at a specified site is an inaccurate procedure when affected by wind conditions, weather, currents, visibility, etc. When tugs are towing barges under cross-wind and/or cross-current conditions, compass headings of the tugs are several degrees off the desired course and are hence useless. The inaccuracies of dead-reckoning can result in material delay in the vessel arriving at the proper site with attendant lost time and increased cost. For this reason, a prototype system was developed by SAI under contract to NED. This system consisted of an Apple II microcomputer equipped with a real time clock, a magnetic disc recording system, and a video monitor. The computer interfaced with a Northstar Loran C receiver, together with a navigation pack serial data output through a Northstar 6700 interface unit. This system provided latitude and longitude coordinates, and range and bearing to destination. These data were shown on a video display to the helmsman. On the display, the vessel's position was shown by a small cross (+) and the track was maintained as a series of sequential crosses. Additional functions, which will not be listed here, were provided by special software developed for the system. The prototype installation provided satisfactory results but was not trouble free.

26. In all of the NYD operations, precisely located taut-wire buoys said to have the capability of keeping station within 1.5 m of exact location were employed. The permits issued by NYD contained specific requirements as to the necessity of accurate disposal and it was also required that Corps of Engineers' inspectors be aboard during disposal operations. The GOETHALS was equipped with a Motorola Mini-ranger in order to provide for accuracy of navigation to and from the marker buoy. The accuracy of this method was estimated to be within 3 m. The quantities of material involved in the NYD operations as compared with the NED operations made it necessary to depart from the NED system of disposing all material at the same precise location and to spread the capping material between 127 disposal points within the Mud Dump Site area. The object was to ensure that at least 0.6 m of capping material would cover the entire area (Morton 1980).

27. A reliable system of measuring and generating a permanent record of the disposal operation is required for any capping activity. Since there are

considerable differences in the site conditions and the weather and sea conditions from site-to-site, a cookbook solution to the monitoring problem probably cannot be developed, but the elements to be achieved are universally required. In the experiments conducted, taut-wire buoys, electronic navigation systems, and government inspectors were relied upon to various degrees to control the disposal activity. Hydrographic surveys, utilizing state-of-the-art echo sounders, were employed to record the fate of the materials handled.

Description of Materials

New England area

28. The dredged material was predominately organic silt and clay of a cohesive nature. The capping material was largely plastic organic silt with some fine sand.

New York area

29. The dredged material was all silt and clay. The capping material was predominately fine sand from the Federal project in Ambrose Channel of New York Harbor, but also contained some uncontaminated silt and clay.

Monitoring Procedures

New England area

30. The monitoring procedures were generally discussed above under "Survey Methods." Those comments had to do with one specific job used as an example of the jobs performed. Since that time certain changes and improvements have been made in the hardware used to conduct surveys. Use of the Hewlett-Packard computer was discontinued. An Apple II microcomputer interfaced with a Model 54 Del Norte Trisponder and a new Western multifrequency fathometer was adopted. The new system was found to be a great improvement over the previous system (Morton 1980).

31. Accurate and frequent monitoring of the disposal area is important when the dredged material capping disposal alternative is used. A careful survey should be made on the grid control used for the predisposal survey as soon as placement of dredged material has been completed. In some instances, if very light materials are being dredged or current conditions are adverse, it may also be necessary to make check surveys during deposition in order to

ascertain how the mound of dredged material is developing.

32. A survey should be made promptly after placement of the capping material. Subsequent surveys should be made at about 3-month intervals until the stability of the dredged material mound has been demonstrated, after which the intervals are lengthened and surveys may finally be discontinued except for special checks after extreme storm events.

New York area

33. Frequent in-house bathymetric surveys have been made similar to those described with respect to NED. These surveys have been supplemented by studies made by the Atlantic Oceanographic and Meteorological Laboratories of the National Ocean and Atmospheric Administration (NOAA).

34. The purpose of all monitoring is to:

- a. Locate and measure the mound of dredged material before capping, determining size, thickness, and volume.
- b. Locate and measure the mound after capping, as to shape, size, thickness, and volume.
- c. Compute quantities of dredged material and capping material placed from a and b.
- d. Analyze and quantify any changes in mound configuration between surveys.
- e. Using sediment samples and chemical tests, determine if the capping material is or is not adequately confining the contaminated material.
- f. Check for the effect of the mound on benthic marine life, and conversely the effect of such life on the mound.

35. Evaluation of the work performed to date in the Long Island Sound and the New York Bight leads to the conclusion that the monitoring procedures in both instances have been thorough and have provided some excellent information relating to the dredging/capping operations.

Physical Site Conditions

New England area

36. All dredging in NED has been maintenance dredging from several Federal project channels, including Stamford Harbor, New Haven Harbor, Black Rock Harbor in Connecticut, and Portland Harbor in Maine. All material to be capped has been disposed at specific marked points within the confines of the

Central Long Island Sound Disposal Area (Figure 3), a rectangular area about 14 miles south-southeast of New Haven, Connecticut (Morton 1980). All capping material from the Connecticut harbors has been disposed at specific marked points within the confines of the Central Long Island Disposal Area. Water depths in the area are about 72 ft. The Portland Harbor material was placed in a rectangular area having depths on the order of 165 to 190 ft (Morton 1980). The disposal areas are subject to the vagaries of weather but are in relatively protected waters having no extreme conditions of tide, swell, or current.

New York Bight

37. All basic dredging in NYD has been performed by permittees from slips and harbor areas not included in Federal navigation projects. All capping material has been secured from maintenance dredging of Federal channels.

38. All material was placed in the Mud Dump Site, a rectangular offshore area in the Atlantic Ocean. The depth of water in the area is on the order of 82 ft. The location (Figure 1) is about 6.8 miles east of New Jersey and 12.4 miles south of New York (O'Connor and O'Connor 1983).

39. Being an offshore area, this area is more exposed to the vagaries of weather than the Long Island Sound Disposal Sites. The range of tide is about 6 ft but no evidence has been noted to indicate that the area is especially subject to extremely adverse weather, except for infrequent major storms.

Evaluation of the Capping Demonstration

40. the capping experimentation in the Long Island Sound and the New York Bight has highlighted the fact that the process is complex. Precise control of the dredging, transporting, and placement of materials with conventional equipment and methods now in common use cannot be achieved. Precise measurement and accurate documentation are important to the understanding of the problems and the identification of the improvements needed. Part II has dealt with the procedures that have been used thus far in attempts to perform capping in the Long Island Sound and to generate useful and accurate data about the deposition and subsequent covering of disposed material in the New York Bight. These experiments are a good beginning in the development of a practical deposition and capping format that may have general application to other regions and in different climatic, geographic, and physical situations.

41. The experimentation with capping in the Long Island Sound Disposal Area and the Mud Dump Site concerned itself primarily with the development of measuring and monitoring methodology. Little or nothing has been done to improve the dredging, hauling, and placement of materials. Numerical models and competent theory have been developed dealing with predictions associated with the short- and long-term fate of material disposed in open water. Yet the severe physical conditions at such sites make accurate accounting for losses or movement of this material difficult in actual practice.

42. Improved technology in the field of electronics, and the application of computers in the positioning systems that are now available, have permitted quite remarkable advances in the measurement processes. The surveys made in Long Island Sound, especially, have provided more data concerning the fate of the disposed material than existed before. These survey data, together with quite extensive work in biological and chemical testing programs that has proceeded concurrently with the capping experimentation, provide good and valuable information that should be built upon by additional effort in these and other locations.

PART III: POTENTIAL IMPROVEMENTS

Conventional Dredging Equipment

Equipment used in field tests

43. In each of the capping tests performed to date by NED and NYD, the dredging of harbor materials was conducted by grab bucket dredging. Transport of the dredged material was accomplished by dump scows towed by tugs. There is no indication that a conscious selection of this method was made especially for the capping studies. Grab bucket dredges are the conventional plant in use for harbor dredging in the Northeast (Figure 9).

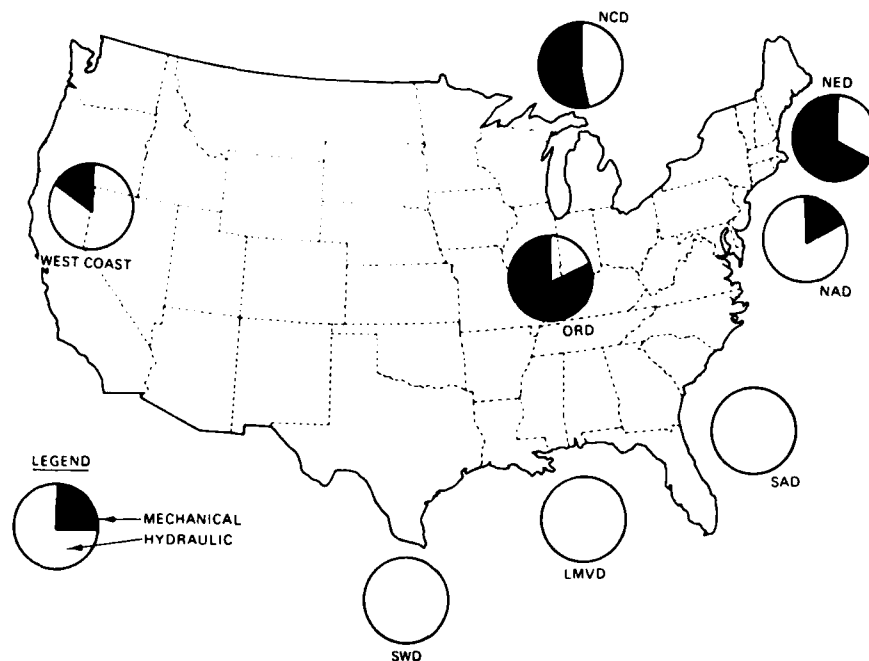


Figure 9. Mechanical versus hydraulic dredges by project. (Basic information from US Army schedule of dredging work for FY 1982, as printed in "World Dredging & Marine Construction," January 1982. Government maintenance work only.)

44. The harbor sediments are described in various ways but each have similar physical properties, i.e., fine grained, silty, and clayey, and are, to varying degrees, cohesive. the quantity of sediment dredged at each job site is relatively small, usually less than 100,000 cu yd. These properties tend

to favor the use of grab bucket machines over hydraulic systems.

45. It is traditional to excavate these small, congested harbors with grab bucket dredges. These machines are essentially floating cranes with free-falling buckets controlled by skilled operators unaided by electronic devices to position the dredge or the bucket while it is under water. The material is raised and cast into a captive barge with bottom-dump doors that are mechanically operated. The barges are most often towed to the site by small tugs on hawsers which can be shortened or lengthened to suit sailing conditions. In good weather, the tug may push or tow from the side of a loaded barge.

46. The DAMOS record of the Long Island Sound Disposal Site clearly shows a characteristic advantage of mechanical dredging and disposal. Morton and Miller (1980) state:

The implications of these conclusions are important to future disposal and/or capping operations. Consolidated, cohesive spoils are common in the New England area, and clamshell dredges which preserve the cohesive nature of the spoils must be used to reduce suspended load and spreading of spoils at both the dredging and disposal sites. Consequently, most spoil mounds will have surface roughness comparable to the New Haven South Site for a period of time after disposal. These features have been observed at the New London site, but the cohesive clumps have broken down over a period of time primarily due to biological activity, but also as a result of fracturing and erosion. (Stewart, 1978)

47. The cohesive clumps mentioned above are reported by SAI divers to sometimes retain the tooth marks from the clamshell bucket after being on the site for a month or more. A cohesive soil mass that can be excavated, loaded into a barge, transported to the disposal site, deposited, and found resting in the mound of dredged material in its in situ condition, with mass and density virtually unchanged, obviously approaches ideal conditions for the capped material. These physical properties are not ideal for the capping material, however.

48. In retrospect, it is safe to conclude that the type of dredging that was actually employed and the transport method used (regardless of its crudeness) contributed to the success of the Long Island Sound experiments.

49. In at least one instance, the clean, noncohesive material used to cover or cap the harbor sediments was material excavated and bottom dumped by

a trailing suction hopper dredge. The material used in each experiment to cover or cap the harbor sediments was silt or sand or a combination. In either case, it was less cohesive than the harbor material that was excavated by grab bucket dredges.

Mechanical dredges

50. Dredging machines are commonly divided generically between mechanical and hydraulic. The physics of the two systems are quite different as the names indicate. The mechanical dredge is any machine that utilizes systems of levers, fulcrums, buckets, ropes, chains, or tackle to produce the mechanical advantage needed to physically lift segments off the bottom to the surface and release these segments close to the dredge. Hydraulic dredges use a centrifugal pump in a closed piping system to slurry the bottom material and propel it as a fluid to a disposal area or into the dredge itself. There are many variations of each of the two dredge types. Some of the differences may have significant impact upon the outcome of a project expected to remove polluted material and deposit it in a controlled disposal area to be capped with clean material.

51. The most common mechanical dredge in the United States is the grab bucket dredge. This piece of equipment is essentially a crane equipped with any of a variety of free-falling buckets designed to fall through the water with hinged jaws set open, engage the bottom, cut into the bottom material as the jaws of the bucket are mechanically closed, and contain the bucket load until it is raised and released into a hopper barge, or cast nearby. Buckets are referred to as clamshell, orangepeel, rock tongs, and others. Clamshell buckets, being the most widely used, also come in a variety of designs. The crane may be steam, electric, or diesel powered (Figure 10).

52. The grab bucket dredge is simple and very versatile. It is probably more correctly classified as a piece of heavy construction equipment rather than a production dredge. There are some disadvantages to the use of grab bucket dredges; among them are:

- a. Smooth bottoms are difficult to produce.
- b. Control of the bucket depends largely upon the skill of the operator.
- c. Very soft or fluid materials cannot be handled.
- d. Unacceptable turbidity often results from material escaping from the bucket.
- e. Production is low and unit cost is high.

Grab bucket dredges are very useful in dredging in cramped quarters, working over and around obstructions, digging material containing boulders and debris, and for salvage work.

53. There has been an interest in reducing the amount of material re-suspended in the water column, notably by the Japanese, and some investigation was conducted by the Corps of Engineers. The Japanese carry out a considerable amount of bucket dredging of fine-grained sediments, including soft muds, which in many harbor areas contain dangerous pollutants. The Japanese have developed "watertight" buckets for use with grab bucket dredges. Such buckets are known to reduce the amount of material agitated and lost overboard in the dredging process (Barnard 1978). An evaluation of the benefit of the watertight bucket design was made by WES in cooperation with the Jacksonville District in 1982 (Raymond 1983). The results were very much in favor of the closed or watertight bucket since it did not measurably reduce production and it did significantly reduce water column turbidity. The test was convincing since it evaluated both types of buckets on the same project at the same time (Figure 11).

54. Even with a large reduction in material lost overboard resulting from bucket improvements, this dredging method is for special projects and has significant disadvantages, not the least of which is its high unit cost.

Hydraulic dredges

55. This report will not recount all the intricacies of the hydraulic dredging system but will distinguish certain characteristics that will be investigated more closely in later parts. Hydraulic dredge types such as side-casting dredges and dustpan dredges which have no obvious application to dredging/capping will not be included in the following discussion (Figure 12).

56. Slurry density. The basic nature of the hydraulic dredging system requires that the bottom material be somehow made into a slurry (a non-Newtonian fluid). The fluid is a mixture of water and solids that acts like a viscous fluid when velocities in the closed system are high enough to keep the solids in suspension. Whether the dredge employs a cutter at the suction end to cut and break up the consolidated sediment (cutter suction dredge), or whether a heavy drag is used to create a high velocity entrance stream that erodes the bottom (trailing hopper dredge), or any number of other schemes to loosen the material for removal, a high percentage of water is always added to produce the slurry which can be handled as a fluid by a centrifugal pump.

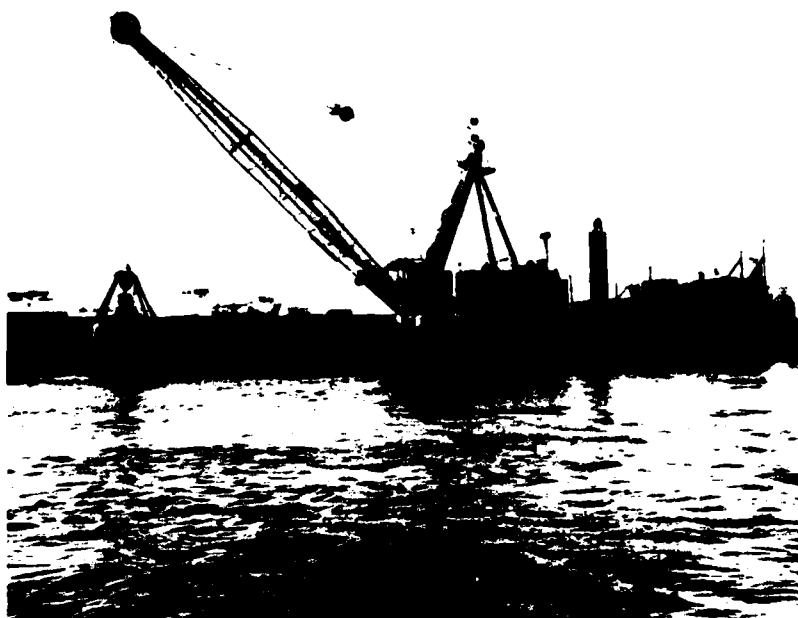


Figure 10. Grab bucket dredge

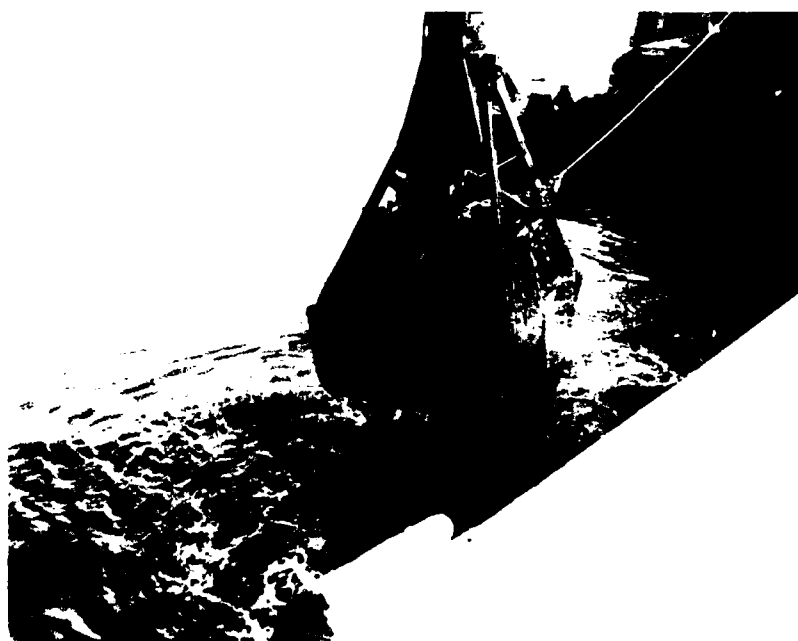
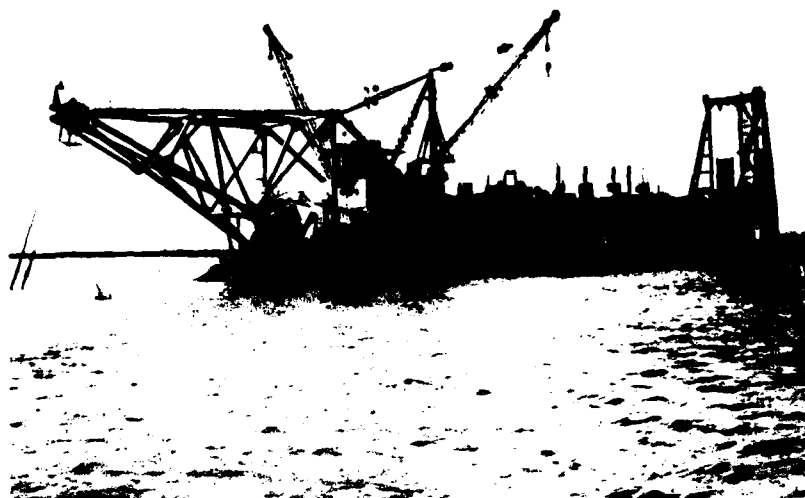
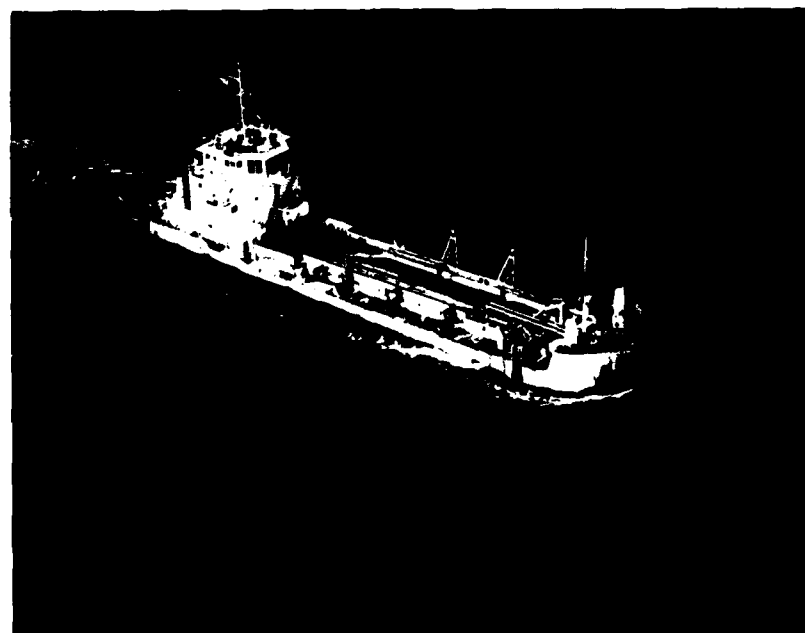


Figure 11. Watertight clamshell bucket during field studies



a. Hydraulic cutterhead pipeline dredge (27 in.)



b. Split hull trailing suction hopper dredge (1,000 cu yd)

Figure 12. Hydraulic dredges

Since the tendency to settle out in the conduit is overcome by maintaining sufficient velocity to sustain the slurry, it follows that if the solids being dredged are heavy "high-dry density," more water is needed to form the slurry. If, on the other hand, the material is fine grained and has a "low-dry density" (silt), less water is required to be added. Studies have revealed that the average density of dredged slurry, for a given system, varies over a narrow range whether the solids are heavy sand (2,000 g/l) or light silts (1,250 g/l). Mohr (1975) asserts that conventional dredging (with dredge pumps at the waterline) produces a slurry of density approximately 1,200 g/l, irrespective of the in-place density. Dredge pumps located on the ladder, or at the suction end, increase the density of the slurry. In spite of the improved designs, it is true that all hydraulic dredges add dilution water and therefore pump a slurry that has less density than the in situ material. Mohr (1975) further shows by calculations that the average hydraulic dredge, regardless of the materials being pumped, adds from one to three parts water to the bottom material (one part water (100 percent) to mud of 1,400 g/l density and three parts water (300 percent) to sand of 1,800 g/l density). This added dilution water creates problems when dealing with contaminated sediments and is the hydraulic system's most unfavorable feature.

57. The thrust of Mohr's argument in the paper cited above is aimed at the relative merits of the dredging system for fuel economies. In other words, if a hydraulic dredge system must handle an average of 2 tons of water with every ton of bottom material, the cost of handling the water alone is significant. The effect of the water on the material being handled is of concern in a physical sense in addition to the economic issue.

58. If dredged sediments are to be transported short distances (within 2 miles) the task is often accomplished within acceptable limits of cost by laying suitable pipeline and pumping a slurry containing a maximum of about 20 percent solids, by volume, to the disposal site. Technically, there is no limit to the distance that slurry can be transported by hydraulic pipeline but the cost increases exponentially as the distance between the dredge and the disposal area increases. Some situations obviously favor the hydraulic system. Satisfactory placement of contaminated silts and coarser grained capping material can be accomplished by adding such features as ladder pumps, booster pumps in the discharge line, and terminal end submerged diffusers to reduce velocity at or near the bottom.

59. Loading barges with a hydraulic dredge. In dealing with materials that must be capped for safety, allowing overflow during barge or hopper dredge filing would be unreasonable. It follows, therefore, that hoppers filled by hydraulic means with such material must be transported to the disposal area with considerable water and relatively light loads.

60. The desirability of flocculating dredged material so that the solids precipitate out and free the dilution water for return to the water course has been the subject of some serious investigation. Heavy sands are immediately consolidated by gravity, but fine-grained materials that are slurried sufficiently to be handled hydraulically have never been successfully encouraged to settle out in short periods of time. The US Army Engineer District, Philadelphia (1969), describes a comprehensive test of the settling of hydraulically dredged Delaware river sediments. A summary statement of that report offers the following advice:

This testing confirmed results of similar testing made in 1974 from which it was concluded that gravitational settling of hydraulic dredged fine-grained material in dredge bins or scows is not economically feasible.

61. Disposing fine-grained slurried material. Fine-grained bottom sediments that have been diluted and agitated so as to look and act like a fluid will behave much differently when deposited than would large lumps of semiconsolidated cohesive soil material. When a sizable load of such material is released suddenly, in 30 to 100 or more feet of water, most of the mass (with a specific gravity of about 1.2) tends to settle quickly to the bottom and then spread laterally (O'Connor and O'Connor 1983). Some, of course, is further diluted by the agitation process of the disposal and remains in suspension to be carried away depending on particle density, currents, water density, temperature, salinity, etc. This condition is undesirable for three reasons:

- a. The fine particles that separate from the low-density mass will carry with them a portion of the total contamination in sediment.
- b. The mound created on the bottom will be of very low density relative to the original bottom material, and will tend to be unstable for some time.
- c. The mechanical bond between the particles is interrupted by the dilution. Interstitial water is increased and therefore exposure of the contaminants to the seawater is increased.

62. While the mound so placed will be more difficult to contain, will require more capping material, and will be hard to monitor, there may be some

situations that would permit barge loading by hydraulic means. If the currents in the area are minimal and the energy level on the bottom remains low for a reasonable length of time, a very high percentage of the load should reach the bottom and immediately begin the reconsolidation process. After all, the sediment in the original dredging area was deposited gradually and in time assumed a semiconsolidated state. It seems reasonable to expect that light or fine-grained material loaded hydraulically and disposed in open water would settle slower, travel further upon encountering the bottom, and diffuse laterally over a longer period of time than if handled in its in situ condition. From this perspective, barge loading by hydraulic means is usually undesirable if capping is required.

Dredge Plant Currently Available

63. By far the most common dredge plant in use in the inland waters of the United States is the cutter suction dredge. The hydraulic machines are highly developed and are becoming even more sophisticated as computer development makes instrumentation a profitable investment. In many parts of the country, cutter suction dredges have virtually replaced all other types except for special projects.

64. Until the late 1970s, all of the United States' oceangoing hopper dredges engaged in navigation maintenance and improvement were operated by the Corps of Engineers. With the exception of the dredges MARKHAM AND MCFARLAND, all of these dredges were equipped with bottom-dump doors and none could operate in shallow water. The small HYDE class dredge, of which four were built during World War II, had a design maximum loaded draft of 12 ft 10 in. (US Army Corps of Engineers 1954). This draft increased as improvements were made and the remaining dredges of this class now draw upwards of 14 ft loaded. It is suggested that hopper dredges may play an important role in dredging/capping operations undertaken in the future in many areas of the United States. In Part II of this report, mention was made of the use of the Corps of Engineers' hopper dredge GOETHALS for placement of capping material by NYD. One of the drawbacks that developed, however, was the inability of the GOETHALS to discharge its load instantaneously. Material bridged and hung up in the hoppers and it was necessary to wash the hoppers out with seawater for perhaps 30 min or more before all material could be discharged. This

inevitably increased the dilution of the material being disposed, increased the turbidity in the water column, and decreased the efficient descent of the dredged material to the bottom. Although NYD reported that the capping placement was successful, there can be no doubt but that the operation would have been even more successful had rapid disposal been possible. All of the older Corps of Engineers' hopper dredges had the same problem as the GOETHALS and it was accepted practice to wash the hoppers out for extended periods while disposal was in progress. The new Corps of Engineers' hopper dredges, the MCFARLAND, YAQUINA, WHEELER, and ESSAYONS, have an increased number of hopper doors and an improved hopper configuration which should correct this problem. The newest and largest industry-owned hopper dredge, the STUYVESANT, has 20 hopper doors that can open simultaneously. It is reported that the dredge can discharge in about 5 min. It is suggested however, that when hopper dredges are proposed for dredging/capping operations, tests be made in advance to ensure that almost immediate disposal is possible with dredges in mind.

65. The Corps of Engineers' fleet of seagoing hopper dredges in 1950 numbered 20, in 1980, 14, and by the end of 1983, only 5. As the fleet of Corps-owned dredges declined, the American industry constructed, for the first time, efficient and versatile hopper dredges designed to compete for new work and maintenance dredging appropriations. The impetus for this change was a strong industry political campaign that highlighted the benefits of private enterprise and called attention to undesirable features of a Government monopoly. The American dredging industry has now constructed no less than 11 hopper dredges, 9 of which are of the split hull design. These dredges should have distinct advantages with respect to immediate disposal as mentioned above. These industry dredges cover an extreme range of sizes and constitute a very versatile fleet capable of doing any work previously done by the Corps' dredges. Two shallow draft vessels of the split hull design are operating on the gulf and Atlantic coasts and two are operating on the west coast.

66. Bucket dredges of the clamshell type are abundant, especially on the Great Lakes and in the Northeast. Track-mounted cranes are often secured to deck barges and used as small grab bucket dredges. Buckets are made in a wide range of sizes and configurations. The design of a bucket has a great influence on the performance of this type of dredging. The clamshell is by far the most popular type with sizes of up to 20 cu yd and larger. Most of these dredges fall in the 1- to 10-cu-yd range.

67. There are a few mechanical dredges of the backhoe, dipper, and dragline types. These dredges are found mostly in the Northeast and Great Lakes areas.

Special Plant Requirements

68. If the price is high enough, and the specifications are clear and unambiguous, the dredging and construction industry in this country can generate fantastic solutions. On the other hand, the same industry can (given the opportunity by a vague and incomplete specification) offer some very poor performances. The system of seeking the low bidder causes this to be true.

69. Special handling of contaminated material and the execution of an acceptable capping operation must begin with clear and specific contract requirements. Such a project may not be satisfied by the application of standard practice or the use of ordinary, locally available equipment. The industry will provide what it must to be competitive, secure work, and make a profit. There are many techniques and devices available if the need for them is demonstrated. Unless such a continuing need is recognized, a proper business decision will always opt to postpone or reject investment in new ideas. The entrance into the field of hopper dredge construction and operation by the American dredging industry illustrates this principle.

70. Conditions and safeguards, once established by contract requirements, can usually be met if the funds are available to sustain the cost. In order for projects to be able to receive the benefit afforded by a legitimized open-water disposal scheme, it is quite possible that unusual requirements must be specified and enforced. The following paragraphs will deal with possibilities that exist and are available to the industry.

Electronic controls

71. One of the problems cited in several of the DAMOS accounts was the occurrence of disposing material outside of a reasonable area of tolerance from the designated mound location (Morton 1980). The state of the art in horizontal positioning systems now provides the possibility for excellent control of this feature. Virtually every dredging contractor now uses some system of integrated electronic hydrographic surveying. Contractors are using positioning systems routinely to control the work of their dredges. Electronic equipment manufacturers have the ability to provide an integrated

system of control that could furnish a permanent record of any barge or hopper dredge operation. Such systems can record with considerable reliability the track of the vessel, the exact position of the vessel when the load was discharged, the time each operation occurred, the load in the vessel (displacement) at any time, and any other information needed, including weather, tide, and current.

72. Should the decision be made to electronically control and monitor the dredging/disposing activity, the Corps may wish to supply the hardware to be placed aboard the contracting vessel, or simply to specify that the contractor supply the specific equipment needed. The idea here is to establish a system, under Corps control, that will provide a permanent record of the track of the vessel and the point of disposal. This is well within the capability of several systems. Payment for material improperly disposed would, of course, not be made and a penalty for misplaced material should be treated in the contract. Such an automatic surveillance system has the potential of improving contractor performance and reducing the cost of Corps inspection.

Self-propelled barges

73. It is obvious that some difficulty occurs in positioning a barge being towed by a tug if the barge is to be emptied at a precise point. Weather and operator skills are factors which cause this problem to occur in varying degrees. The placement of the dredged material to subsequently be capped may require a level of precision that justifies the use of only self-propelled barges (Figure 13).

74. Self-propelled barges, equipped with Loran and a reliable horizontal positioning system compatible with District owned and operated electronic tracking or plotting devices, could improve the chances of public acceptance and counter some of the criticism of the ocean-disposal practice.

Split hull dredges

75. The recent innovation of the split hull dredge design has provided a substantial benefit to the capping technique. Before the prototype dredge CURRITUCK was constructed (1976), all hopper dredges were equipped with multiple hoppers and an array of hopper doors (Figure 14). The material usually bridged in the hoppers and required quickening with jets or wash-water to dislodge the load. Disposal often required as much time as loading and the dredge traveled a considerable distance during the process. The split hull



Figure 13. Self-propelled barge under way

design allows the discharge of a variety of materials to be almost instantaneous, prevents bridging of the material in the hopper, and makes washing the material from the hoppers unnecessary. Thus, the accuracy of positioning the disposal is improved and the material is less likely to be lost by contact with the water column. On critical projects, it may be advantageous to specify that the dredge be of the split hull design for these reasons.

76. The first split hull dredge was introduced into the United States by the Corps of Engineers. In 1973 the Wilmington District constructed a self-propelled split hull barge which had many features of the vessels constructed in Europe by Selma H/S of Oslow, Norway. It was converted into the first US split hull dredge in 1976. This conversion involved the permanent installation of the dredging system in the two hulls of the dredge using through-hull trunions and a fixed distribution system. A recent innovation accomplishes such a conversion by prefabricating components needed for a complete dredging system, including power plant and a single dragarm mounted pump, so that they can be placed aboard a split hull barge in portable

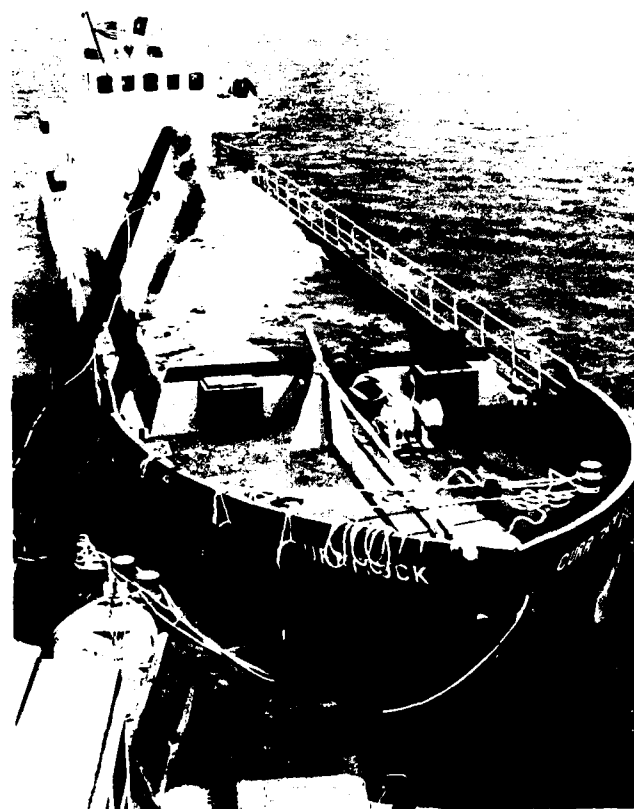
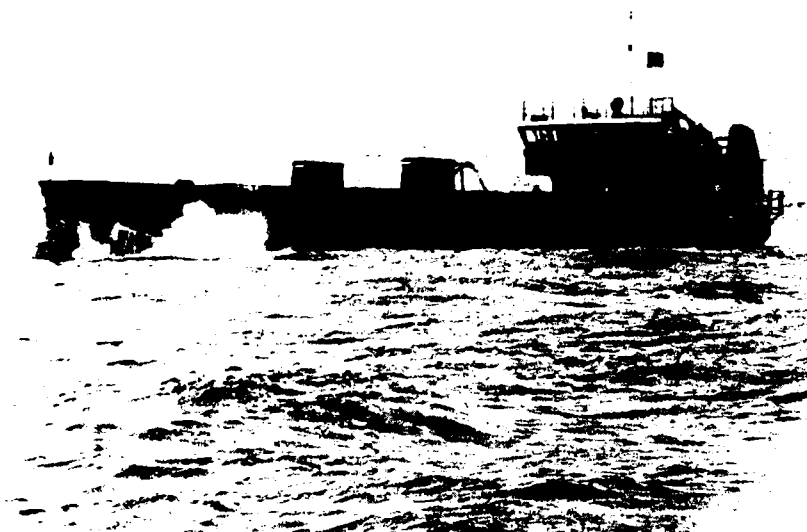


Figure 14. Corps of Engineers split hull dredge CURRITUCK. This is the prototype of industry's split hull dredges

fashion. Thus, any split hull barge can be quickly and perhaps efficiently converted into a self-propelled hopper dredge. The point is that hydraulic excavation of harbor sediment is no longer dependent upon a nearby disposal area (pipeline dredge system) or upon an expensive seagoing hopper dredge due to dredge plant innovations perfected in this country and borrowed from abroad.

Specialized barges

77. In some cases, investment in special equipment for the transporting and placement of harbor dredging and cover material will be justified. The conventional disposal method may not be satisfactory in all cases.

78. Japan has accepted the fact that extreme costs must be paid for acceptable pollution control and even the rehabilitation of seriously polluted ocean and bay bottom. Japan's experimentation and prototype testing of equipment for such work may prove beneficial to the United States, at least for extreme cases in the future. The Japanese effort is directed toward covering rather extensive seafloor areas with clean dredged sand. Two papers were recently published by members of the Japan Dredging and Reclamation Engineering Association (Togashi 1979, Kikegawa 1980). These papers describe two innovations, the use of a sand spreader (hydraulic) and a conveyor barge with a tremie pipe (mechanical).

79. The procedures described by Togashi and Kikegawa employed some rather large and elaborate equipment that had been developed for other uses. The aim of the test was to perfect a technique for distributing the sand cover material with great care and precision, exactly 50 cm thick over a soft contaminated bottom. The dredging and disposal of polluted material was not discussed and it was evident that the contamination already existed and was widespread over an extensive area of the Seto Inland Sea. The bottom, in one instance, was described as contaminated sludge, being very soft. One concern expressed was the need to prevent disturbance of the existing bottom and to preclude displacement of it by overlaying with sand too thick to be supported by the low-strength substrate. These conditions, together with an extreme environmental concern, dictated the need to develop a precision system that could be carefully controlled and measured.

80. Sand spreader. This specialized device is almost a hydraulic dredge in reverse. It consists of the following features (Figure 15):

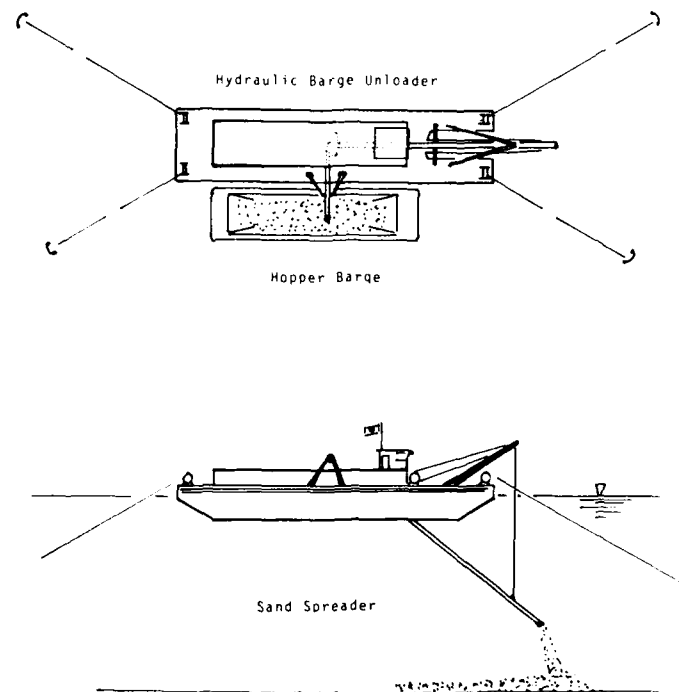


Figure 15. Hydraulic barge unloader and sand spreader
(redrawn from Kikegawa 1980)

- a. A barge similar to a pipeline dredge.
- b. A gantry for handling a submerged pipe.
- c. A sand pump for transferring the sand from a hopper barge to the submerged pipe.
- d. A manifold at the discharge end of the submerged pipe to distribute a sand/water slurry.
- e. Water pump system to supply mixing water to the sand in the hopper barge.
- f. Winches for handling hauling wire at each of the four corners of the sand spreader barge.

81. The machine is put on station and supplied with sand material by hopper barge, unloads the barge hydraulically, and pumps the sand/water slurry through the submerged pipe to the bottom. The entire system is swung from side-to-side and winched ahead for a new "set" by hauling wires attached to four winches.

82. Such a device allows precision placement of the sand blanket not possible by dumping. The hydraulic barge unloader is often used in unloading sand and gravel barges at dockside. The difference is that the sand is piped from the barge in the form of a slurry to a stockpile at the processing plant,

rather than distributed overboard as a blanket on the bottom.

83. Conveyor barge. This adaptation of another sand and gravel unloading system was employed to accomplish the same purpose as mentioned above. The system permits a barge equipped with a conveyor unloading system to discharge cargo (without adding water) directly into a tremie pipe fitted to the barge discharge port (Figure 16). The tremie was the innovation; it was made in sections so as to be telescopic, probably handled with a special winch working two wires attached to the larger, lower section of the pipe. The barge was put on station, swung from side-to-side by swinging wires, and the sand distributed much like the sand spreader.

Drag scraper unloading systems

84. Recovery of construction aggregates mined from the ocean is very important in some parts of the world. Some of the equipment mentioned above was adopted from Japanese aggregate handling procedures.

85. British Ropeway Engineering Company, Ltd., specializes in the development and manufacture of systems that utilize mechanical devices to load, unload, and handle mined materials. One such device is an adaptation of drag scraper buckets inside ships and barges which constitutes a self-

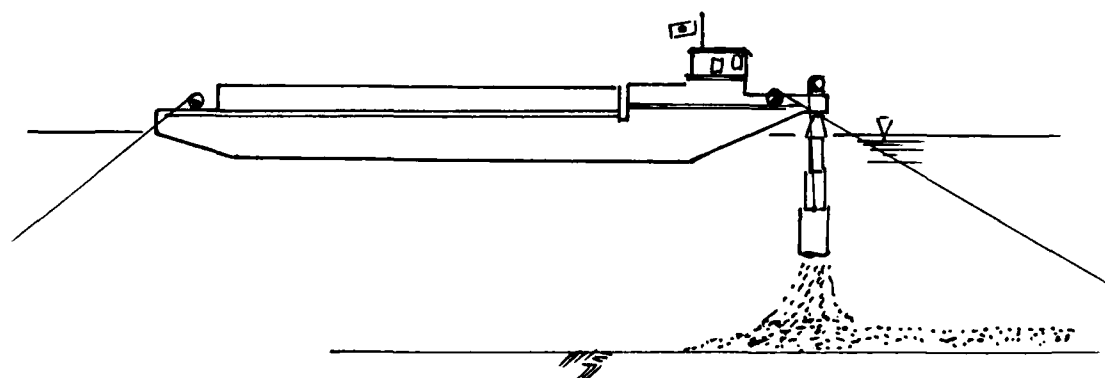


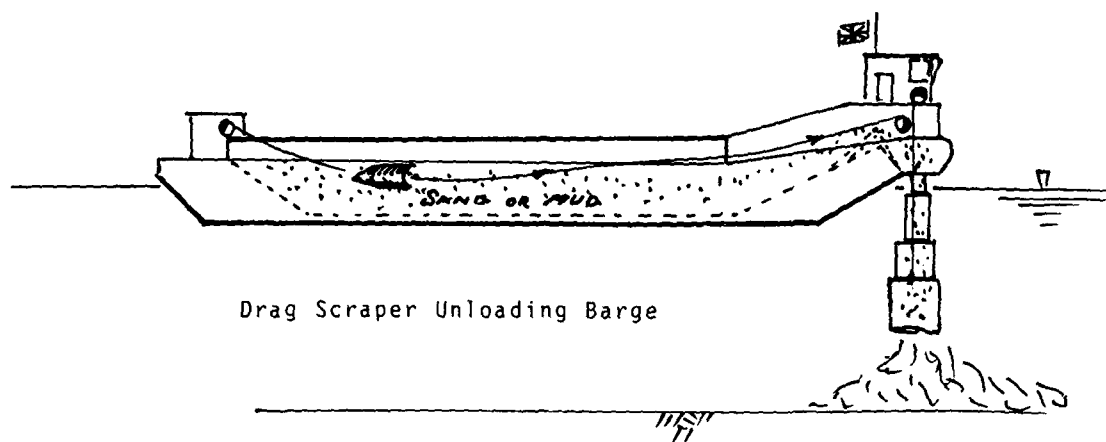
Figure 16. Conveyor unloading barge. Any barge equipped with conveyor or bucket wheel unloading system can be modified to discharge into a tremie as this sketch illustrates (redrawn from Togashi 1979)

unloading feature. Winches pull the buckets into the material much like the "slack line excavator" seen on large, land-based projects. The buckets travel toward the discharge hopper of the loaded vessel bringing a measured amount of material, the buckets dump into an unloading hopper, and the direction is reversed and the scraping process continues. Such unloading of noncohesive

materials is fast and efficient. Buckets used for these purposes are essentially bottomless scoops which take advantage of the free-flowing nature of the product being handled. With mud, silts, saturated fine sands, etc., it would be necessary to utilize a bucket that is designed to dig into the material in the same manner that a dragline bucket does. Cohesive materials could be unloaded with this system if arranged appropriately (Figure 17).

86. Contaminated muds and cohesive materials could be loaded into such a self-unloading barge by hydraulic or mechanical means. The contents could then be unloaded by the drag scrapers into a tremie device similar to the Japanese conveyor unloading barge. The tremie innovation would refine the unloading process and allow very precise position control of the deposited material and minimize its contact with the water column.

87. Material to be used for capping the contaminated deposits could, of course, be handled and distributed in the same manner with the same equipment. Granular material would work much easier than the consolidated or stiff muds and silty clays and sands that are likely to be characteristic of the sediments to be covered.



Sketched from literature by
British Ropeway Engineering Co., Ltd.



Figure 17. Drag scraper adaptation to barge unloading

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Justification for Capping

88. The special handling required to execute a capped disposal project will increase the cost compared with a conventionally executed maintenance dredging contract. How much of an increase depends upon many variables that are site specific. If the contaminated material can be handled satisfactorily with conventional dredging equipment, and it can be disposed in the usual manner, and if adequate capping can be secured from a nearby active dredging project, the additional cost will be minor. It should be expected, however, that the added cost may be significant in most cases and this should encourage careful planning. Planning and evaluation are necessary in order to:

- a. Preclude the use of capping in cases where the risk is minimal or the need cannot be established.
- b. Accurately evaluate the alternatives, if any exist, to identify the cost of other disposal or treatment methods.
- c. Schedule the dredging of the harbor sediment and the capping material so as to minimize the haul distances and avoid doing useless work.
- d. Structure the special contract provisions so as to allow the use of the most appropriate methods and equipment that will produce acceptable results.

89. At this stage in the development of the capping concept, and in the absence of rational capping performance criteria, it is not reasonable to develop a list of projects that will be likely candidates. Neither is it reasonable to exclude projects or geographical areas from the possibility of resorting to this method of disposal.

90. In connection with the idea of taking measured precautions in justifying the use of a capping procedure in the first place, the decisionmaker should take note of the excellent investigation done since 1972 by WES under the DMRP. O'Connor and O'Connor (1983) is an impressive literature search and commentary on the subject of known and imagined consequences of ocean disposal. The report cites 126 technical references which may be the majority of the total literature on the subject.

91. The planning and design people who will affect decisions concerning ocean disposal, and especially the selection of a capping program, should study the O'Connor report and its references. The sense of the report is that:

- a. The contaminated sediment has far less effect on the water above it, and the animals that live in it, than is generally believed.
- b. Considerable evidence suggests that the contaminants in the sediment remain associated with the particles and tend not to dissolve or otherwise disassociate from the deposit to the extent commonly believed.
- c. Studies on fish, crustaceans, mussels, and clams showed no greater contaminant accumulation at the disposal site (New York Mud Dump Site) than at other stations in the region.
- d. The practice of capping the contaminated sediments produces beneficial results.

Dredging Improvements

92. Placing the cap on an open-water disposal mound is but one phase of a multiphase system of dealing with contaminated sediment. The sediment must be (a) dredged from the bottom, (b) transported to the disposal area, (c) deposited in the preselected site on the bottom, and (d) capped with suitable material. Lifting the contaminated sediment through the water column at the dredging site with the very minimum disturbance, creating the minimum turbidity, and causing the least change in the soil structure is the objective of the dredging process.

93. Conventional dredging equipment operated in the conventional manner receives poor marks. Hydraulic systems add dilution water and change the physical character of the bottom material. All wire line mechanical dredges cause much agitation during the digging and lifting process, leave rough bottoms, and produce high unit cost.

94. The most promising method of removal, with minimum disturbance and maximum control of the dredging process, is by utilizing a modern ladder bucket machine. This "old" concept should be adopted by the United States and modernized with state-of-the-art instrumentation, so as to benefit from its inherent advantages of:

- a. Removing bottom materials in in situ condition.
- b. Responding to sensitive control of speed and bucket filling and the production of level bottoms.
- c. Loading barges with solids without the need for overflow to achieve "economic" load.
- d. Improved production over other mechanical dredges, i.e., less unit cost.

e. Creating less turbidity at the digging level.

95. Improvement in dredging and in barge loading is required if the capping technique is to be significantly advanced. It is suggested that a dredging process totally different from the conventional harbor dredging method be investigated. The Corps of Engineers should procure, instrument, and operate, at least for a reasonable length of time, a mechanical ladder bucket dredge plant to perfect its advantages and document its benefits and costs.

Hauling Equipment

96. The conventional barge equipment used in the United States for the transportation and deposition of dredged and other waste materials are generally very crude vessels that must be towed by tugs and usually have separate hopper compartments with individually operated dump doors through which the material is discharged. The objections to the majority of the dump barge operations is that the barges cannot be dumped quickly, the tugs often cannot position the barges accurately, and they can seldom be held stationary at a disposal position if need be. Many in use are in poor state of repair and often leak material from the loading to the disposal site in significant quantities, making mass volume calculations erroneous.

97. In cases requiring good control, where capping is justified as a mitigation measure, improvements must be made in the equipment and procedures for transporting and disposing the dredged material. A far better vehicle for handling such material is the self-propelled split hull barge. Precise control of such vessels during the transportation phase can be ensured by modern electronic navigation systems, disposal at a very precise assigned coordinate is achievable, and the ability to discharge virtually instantaneously is a very beneficial attribute. Large fleets of self-propelled barges have been working in European waters for many years and they are accepted as being economical and efficient. The first such vessel in the United States was constructed by the Corps of Engineers. There are yet few, if any, self-propelled split hull barges operated in conjunction with dredging and disposal of dredged material in the United States. To achieve the improvements needed in the hauling equipment, project specifications could insist upon use of properly equipped, self-propelled split hull barges.

Positioning and Surveillance Technique

98. Technological developments in electronics and especially micro-processors have resulted in the development of precise and reliable positioning systems that are offered at reasonable prices. Integrated systems for surveying and for dredge (or barge) positioning can achieve remarkable results. It is suggested that Corps of Engineers specifications must demand a high degree of sophistication in the use of these systems and specify performance levels that will ensure precise positioning. Further, it is imperative that the Corps, working with the electronic industry, develop a reliable system that will permit electronic surveillance of all transportation and deposition of dredged and capping materials placed in a disposal site. The technology is available now and when the need is manifest by contract specifications, the equipment will be provided. The goal is to establish tolerances for each site and to place electronic equipment aboard each vessel and integrate it in such a manner that a recording on a master instrument will show exact location, time, and the weight of the load disposed. An endless array of parameters, including tide corrections, current velocities, wave heights, and bottom shear forces, can be added to the system with today's technology.

99. The present practice of finding a buoy at the site and dumping nearby is not nearly good enough to ensure that a capping procedure is adequately executed. Reliance upon Government inspectors who, as in the case of the Long Island experiments, are placed aboard the tugs is a system that at best is subject to human failures and depends upon the accuracy of a person's perception of distance, of direction, and especially of the cargo volume at time of disposal. Manning each barge and dredge with a Government inspector is expensive and possibly beyond reason for the future.

100. Electronic surveillance that provides a written record of each event that takes place is necessary if material is to be accounted for with reasonable accuracy. It is suggested that the Corps should provide electronic equipment and control the master station that would record the data.

Monitoring by Hydrographic Survey Methods

101. The development of systems, procedures, and techniques for monitoring the disposal sites before, during, and after disposal is a subject for which the Government must assume responsibility. The contractor that performs

the dredging should not be expected to be impartial with the measurements of the results of his work. It is unlikely that the Corps Districts will be given the manpower capability to perform the necessary surveys and tests required for a reasonable monitoring program. Surveillance, including the hydrographic work, will probably be done by contract under the supervision of the Corps District responsible for the project. The Government's interest, however, must be such as to encourage technical advances and perhaps new inventions in the equipment used in such monitoring programs.

102. Hydrographic surveying is a field in which the Corps of Engineers' influence has been considerable, because the Corps was a principal user of the technology. Even with the considerable offshore activity by other various interests, the Corps is perhaps the only entity that is concerned with precise bathymetric measurements. For those who are concerned with ocean-bottom mapping, exploration, navigation, and the like, the matter of a foot, or a metre, or even a fathom is considered adequate accuracy. In monitoring the behavior of disposed sediment, as in the measurement of work to be paid for by the measured volume, precise measurements on the order of one tenth of a foot become important. Calculations of volumes between subsequent bathymetric cross sections are commonly made assuming an accuracy of the survey data of one tenth of a foot. Such accuracy is seldom actually attained and should not be expected in the ocean environment when using conventional state-of-the-art systems. The reason for this poor performance is not in the accuracy of the equipment used but in establishing and continuing a datum from which the replicate surveys are made. The standard procedure to calibrate the on-board survey electronics is by passing a metal bar a known distance below the acoustical transducer of a survey vessel's fathometer and adjusting the instrument to produce the known value. This does nothing to establish a datum or benchmark from which to measure the elevation. Suffice it to say that in an area far removed from a land-based benchmark, it is impossible with the standard survey methods to establish the elevation of a floating object to the accuracy needed, i.e., a tenth of a foot. Since the surveying instrument is floating on the surface of a constantly changing sea level and there is no way possible to estimate the elevation of this surface at the vessel location, using a sea level datum introduces a large random error in the mass volume calculations.

103. The work done in the Long Island Sound utilized a method of physically matching the outer edges of the bottom signature of replicate surveys

as recorded by the survey fathometer. This assumes that the match point chosen has not changed since the previous survey. Error may be introduced by this assumption.

104. If accurate calculations of volumes are to occur, the establishment of a reliable and very stable benchmark at the survey site is necessary. Tide gages have been erected at some dredging locations in open water to provide a datum (Figure 18). Such structures are difficult to maintain in most open-water locations. Certainly the Mud Dump Site is a very unlikely place to expect a fixed structure to remain for any appreciable time; actually no structure erected in the ocean is really "fixed" over any reasonable length of time.

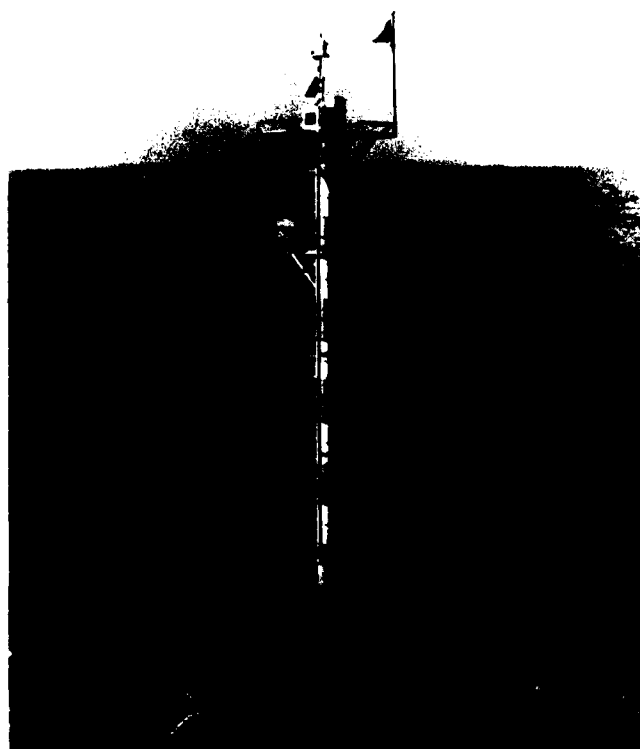


Figure 18. Tide gage installed in 1977, 3/5 mile seaward of Beaufort Inlet Bar, North Carolina. Device equipped with telemetry package utilizing VHF-FM transceiver

105. It is suggested that the problem of survey datum is one that must be solved for each proposed location before any serious attempt is made to account for the mass volume of disposed material or even the behavior of the

mound in precise terms. The Corps of Engineers should undertake a research and development (R&D) effort aimed at the development of equipment and systems that will give reliable and long-life performance as a benchmark in typical ocean disposal areas. In the meantime, it appears that the implantation of a mass of concrete or metal sufficiently large to ensure an easily discerned fathometer signature may be a direct albeit primitive method of improving the results now being obtained. Any mass placed on the bottom will tend to settle and, if sufficient current is present, may tend to "sink" for some time. If this crude system is employed as a benchmark, reference points and diver observations would be a necessary adjunct.

Disposal Technique

106. The present practice of allowing the dredged material to free-fall through the water column, for 100 or more feet, ensures that at least a small portion of the material is lost. The amount of solid mass that is lost depends upon many things. The important thing is that neither this quantity nor the significance of such loss can be predicted. It is believed that the contaminants are generally held on the finer particles and it is known that the fine particles are usually propelled the greatest distance when in suspension. The ideal situation would be for 100 percent of the solids that are disposed to settle to the bottom and remain immobile in a discrete mound. When employing conventional equipment, managed and operated in the conventional manner, some of the material will inevitably be lost in the disposal process.

107. If there is dissatisfaction with the results of the present practice of disposal, there are alternatives that will ensure better results. The material can be transported from the barge to the bottom in a closed conveyance. The sand spreader and the conveyor unloading barge are two devices that can be adapted to dredged material placement in reasonably deep depths. Special plant will be required and experimentation will be necessary to develop the equipment and refine the procedure. Certainly, such systems can be easily perfected even though they may not presently exist in suitable form.

108. Placing the dredged material in mounds on the bottom by means other than disposal from floating hopper dredges or barges is possible and involves rather simple adaptations of existing equipment. The added cost, compared with the conventional disposal methods, may be on the order of magnitude

of two or three times the cost of transporting and disposal by hopper barges towed by tugs. If justified, the solution is available. A pilot program involving the construction of a hydraulic unloader that could operate at the disposal site and/or a conveyor or scraper unloader that could discharge into a tremie could be developed for placing material directly on the bottom. Full-scale prototype observation will be required before the cost and real benefit can be evaluated.

109. Before experimental equipment becomes available to transport the dredged material directly to the bottom, it will probably be necessary to proceed with the equipment at hand. As previously stated, this presently consists of split hull barges which are self-propelled and equipped with sophisticated horizontal positioning equipment making the unit capable of precise control. Disposal, if almost instantaneous, will cause a different reaction between the material and the water column, and with the bottom, than has been observed in previous experimentation.

Planning Imperatives

Techniques available today

110. If a project must be planned today with a requirement to place contaminated harbor dredging in open water to be isolated by a subsequent layer of capping material, and no opportunity is available for equipment development and further experimentation, the program followed by the NED would probably be a realistic model. This is essentially a scenario that allows contemporary methods, locally available equipment, standard practice, and adherence to the Corps of Engineers' policy of specifying so as to attract the lowest responsible bidder. Such a design will require a modest budget for additional inspection and a contract for monitoring. Such construction specification would not exclude any of the usual maintenance dredging bidders or their equipment.

111. If capping must be designed with the objective of achieving the maximum probability of success using available but not conventional technology, different equipment provided by industry, or by the Government must be specified. Such a project specification will increase the cost of dredging, disposal, and capping compared with the conventional methods. This increase is dependent upon a number of factors, most of which would be site specific.

112. A proper dredging specification would require certain equipment selection for the dredging, hauling, and deposition phases of the work. The planner would exclude certain contemporary equipment in favor of the kinds of equipment described in this report. In order to improve the chances of better contractor performance, the following should be provided for in a contract designed for present day bidding:

- a. Dredging to be done by clamshell utilizing approved closed or watertight bucket operated as directed by the contracting officer.
- b. Hopper barges to be of the split hull self-propelled type equipped with a horizontal positioning system to be specified (or furnished) by the Government.
- c. Hopper barges to be loaded to overflow only and must be proved to be leakproof with the type of material being dredged.
- d. Barges to be equipped with approved load meters digitized to be compatible with the data collection system specified (or furnished) by the Government.
- e. Barges to dispose only at the specified coordinate, and only while the barge is not moving.
- f. Suspension of work to occur in the event the Government determines that the physical conditions at the site are unsuitable, or the electronic surveillance system malfunctions.

113. Separate contracts for surveying and monitoring should be awarded. The monitoring contract should require at least:

- a. A benchmark system of establishing common points for all surveys.
- b. A grid layout as in the Long Island Sound work.
- c. Settlement plates or graduated rods embedded in the bottom, designed to withstand the disposal, so as to provide settlement and consolidation information for at least 1 year after the capping is complete.
- d. Diver observation and surveillance with numerous sampling schemes designed to generate information on the physical properties of the mound as well as the biological aspects.
- e. Sampling program designed to ensure that the deposited material, the original ground, and the capped layer are discerned and measured as consolidation progresses.
- f. Electronic monitoring system to record position of barge in route and at disposal site and to indicate the draft at the time of disposal and after disposal. Real-time record of events and other physical data from monitors at the site.

Techniques not yet perfected

114. For long-range planning, a continuing R&D program should focus on adding to the information secured thus far in the Long Island Sound Disposal Site and the Mud Dump Site. Special plant development should be undertaken, preferably as a Government project, whereby the Government would procure and modify the plant in order to perfect operating techniques and to evaluate performance.

115. The main objective of improved techniques and specialized equipment would be to increase the degree of control to the point of significantly improving the mass volume inventories and to add a dimension of precision that would reduce the likelihood of misplaced material. A better cost versus production relationship would result from these improvements but that incentive is not presently strong enough to motivate private industry to develop the new equipment at their expense. Once new systems are perfected and the cost and benefits are established by prototype demonstrations, the decision can then be made concerning mandatory use. When project requirements (construction contract specifications) clearly call for the use of specialized equipment and specifically detailed results, the dredging industry will be motivated and the needed changes will occur.

116. The items that should be examined for possible prototype development and experimental use include:

- a. A ladder bucket dredge capable of a sustained production of about 800 cu yd per operating hour.
- b. Self-propelled split hull hopper barges to work with the ladder bucket dredge.
- c. Continued R&D with the electronic industry participation with a view toward improving surveillance of the total process and precision of survey measurements.
- d. A hydraulic barge unloader capable of handling a variety of dredged materials and depositing dense slurry directly on the bottom.
- e. Examination of mechanical barge unloaders with a view toward possible full-scale prototype evaluation.

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